# ASSESSMENT OF NONPOINT SOURCE POLLUTION IMPACTS ON GROUNDWATER IN THE HEADWATERS OF THE NORTH FORK OF THE KENTUCKY RIVER BASIN

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# EXECUTIVE SUMMARY

## ASSESSMENT OF NONPOINT SOURCE POLLUTION IMPACTS ON GROUNDWATER IN THE HEADWATERS OF THE NORTH FORK OF THE KENTUCKY RIVER BASIN

## SECTION 319 NONPOINT SOURCE PROJECT - FFY 1998

The goals of this project were to assess nonpoint source (NPS) impacts on groundwater primarily from improper or "straight pipe" sewage disposal and secondarily from coal mining in a portion of the North Fork of the Kentucky River Basin in Letcher County. The Kentucky Geological Survey estimates 70% of the residents use groundwater as the source of drinking water (Carey and Stickney, 2001). The area has well documented problems related to the discharge of untreated domestic waste directly to surface water through "straight pipes", but the impacts to groundwater are less well known.

Most of the soils in Letcher County are unsuitable for conventional on-site septic systems (USDA-SCS, 1965). The area's highly dissected topography concentrates the population in the stream valleys, where close spacing of homes and small lot size makes the use of conventional septic systems impossible or ineffective for most existing homes. Low incomes and high unemployment have limited the use of expensive alternate on-site disposal systems. Because of these factors, wells are vulnerable to NPS pollution, especially if they are poorly constructed or maintained.

To solicit participation in this project, door-to-door surveys were conducted on Crams Creek, Pine Creek, and Bottom Fork roads. Participants' wells or springs were inspected and property was surveyed for potential sources of NPS pollution. Participants were counseled individually and provided information on water quality, analytical results, well maintenance, and any other pertinent environmental issues.

Eighty-seven wells and springs serving an estimated 350 persons were included in the study:  31 properly constructed drilled wells, 40 drilled wells that did not meet current standards, nine shallow hand-dug wells, and seven water supply springs (including two mine adits.)  Field-tests for nitrate-N, nitrite-N, ammonia-N, detergents, phosphate, pH, conductivity, soluble iron and manganese were conducted on all wells and springs and several samples were confirmed by laboratory analysis.  Twenty participants opted for additional biological testing for total coliform, *E. Coli* and fecal coliform bacteria.  Caffeine (and metabolites) were analyzed on wells and springs with significant bacteria contamination.

Although detections of nitrate-N and ammonia-N indicate NPS impacts, probably from straight pipe discharge of wastes, no pervasive or widespread NPS pollution of groundwater was found in this study.  However, groundwater is threatened locally by numerous potential NPS sources.  Other important concerns for groundwater users are substandard well and distribution system construction and inadequate system maintenance and disinfection.  The project demonstrated that on-site inspection by trained personnel is a viable method to promote the protection and appropriate use of this resource.

Hand-dug wells showed little indication of NPS pollutants such as $NO_3^-$, $NO_2^-$, $PO_4^-$, Fe, Mn, or low pH from septic systems or mining, but bacteria were significantly higher in these wells than in drilled wells.  Bacterial contamination is common in hand-dug wells because these wells produce shallow soil water where bacteria flourish and because these wells are inherently difficult or impossible to disinfect and seal.

Eight samples (9%) collected in the study contained detectable quantities of nitrate-N, but none exceeded the nitrate-N Maximum Contaminant Level (MCL) for drinking water of 10.0 mg/L. Fifty percent (50%) of the hand-dug wells compared to only 13% of the properly constructed wells contained nitrate-N. Ammonia-N was detected in 16 of 83 samples, or 19.3%. Anionic surfactants, an indicator of soaps, detergents, and oil and gas drilling foams were indicated by field tests in eight, or 9.2% of wells.

Residents claim that coal mining has impacted groundwater quantity in the area, but water quantity was beyond the scope of this investigation. However, for the limited parameters included in this study, no widespread impacts on water quality from mining were noted.

# ASSESSMENT OF NONPOINT SOURCE POLLUTION IMPACTS ON GROUNDWATER IN THE HEADWATERS OF THE NORTH FORK OF THE KENTUCKY RIVER BASIN

**SECTION 319 NONPOINT SOURCE PROJECT - FFY 1998**

## Introduction and Background

The primary goals of this project were to assess nonpoint source impacts on groundwater in a portion of the North Fork of the Kentucky River Basin (Figure 1), and to share that information with local citizens and officials. The area included in the study is generally east of Whitesburg in Letcher County, on Cram Creek, Pine Creek and Bottom Fork roads (Figure 2). Groundwater is especially important in this area because wells and springs are the primary source of domestic drinking water (Kentucky Department for Environmental Protection (DEP) Consolidated Groundwater Database, 2001). In addition, public water lines are not scheduled for installation in the near future (Letcher County officials and the Mountain Association for Community Economic Development (MACED) North Fork Task Force, personal communication, 1999).

The study area lies within the Eastern Kentucky Coal Field physiographic province on the north side of Pine Mountain. The topography consists of steeply incised, narrow valleys, with narrow ridges and elevations range from about 1200 ft. to more than 2000 ft. above sea level. The area is underlain by Pennsylvanian age clastic sedimentary rocks (sandstone, siltstone, shale and clay) with significant coal beds. Regional dip is to the northwest at approximately 120 feet per mile. The Pine Mountain overthrust fault system is the approximate southeast border of the study area. The proximity of this major structural feature makes the geology of the study area complex, characterized by folding, faulting and steep dips. The complex geology combined with the standard bedrock “open hole” well construction that interconnects aquifers made correlating the well samples to a particular geologic unit virtually impossible. In this physiographic province, drilled wells typically produce water from fractured formations, including coal beds, though significant inter-granular porosity is known to occur in some sandstones. Shallow hand-dug wells produce local soil water and springs in this study reportedly produce from the Mississippian-age limestone, except for the two mine adits, which are constructed into Pennsylvanian coals and clastic sedimentary rocks.

Well-documented straight pipes discharge raw sewage to the surface and to surface streams in the study area, and although effects upon surface water quality are well known, the impacts to groundwater are less studied. One to three thousand straight pipes are estimated to exist in Letcher County (MACED, 1999). Since groundwater and surface water are conjunctive, contamination can spread between these systems. Because groundwater provides the base flow for the streams, including the North Fork of the Kentucky River and its headwaters, any groundwater contaminated by straight pipes may contribute to surface water pollution.

Most of the soils in Letcher County are unsuitable for conventional on-site septic systems (USDA-SCS, 1965). In addition, the highly dissected topography of the region tends to concentrate the population in the stream valleys where close spacing of homes and small lot size, combined with poor soils, have made the use of conventional septic systems impossible or ineffective. Low incomes and high unemployment have also hampered the installation of suitable on-site disposal systems for these homes. Because of these factors, groundwater and wells are susceptible to nonpoint source pollution, especially if the wells are improperly constructed and maintained, including periodic disinfection.

Letcher County officials and the Mountain Association for Community Economic Development (MACED) North Fork Task Force (personal communication, 1999) reported the Health Department found more than 90% of the groundwater-based drinking water supplies they tested in Letcher County tested positive for coliform bacteria. However, as shown by O'Dell and O'dell, (1997), their data consist only of total coliform bacteria, which is ubiquitous at the earth's surface and is therefore not a good indicator of NPS pollution. Health department bacteria sampling results throughout the state also are biased because sampling is only conducted in response to complaints. In addition, wells and distribution systems, which are commonly poorly maintained by private system owners, historically have not been disinfected before sampling. Further, Quality Assurance/Quality Control (QA/QC) procedures must be rigidly followed in order to collect and deliver viable bacteria samples. Well and spring samples may be compromised by exceeding holding times, improper sampling, handling, storage, and shipment. A large percentage of positive bacteria results are estimated to be the result of inadequate QA/QC and contaminated distribution systems rather than contaminated groundwater (see Burlingame and O'Donnell, 1994). For these reasons, the Division of Water proposes that much of the historical bacteriological data collected throughout the state is unreliable indicators of groundwater quality.

In order to properly assess true groundwater quality and the potential impact of nonpoint source pollution (and not artifacts of the distribution system), investigators in this study followed strict QA/QC procedures. Distribution systems were inspected to eliminate them as possible sources of contamination, and fresh, untreated groundwater was collected for analysis. In addition to total coliform, E. coli and fecal coliform bacteria, and nutrients were also analyzed.

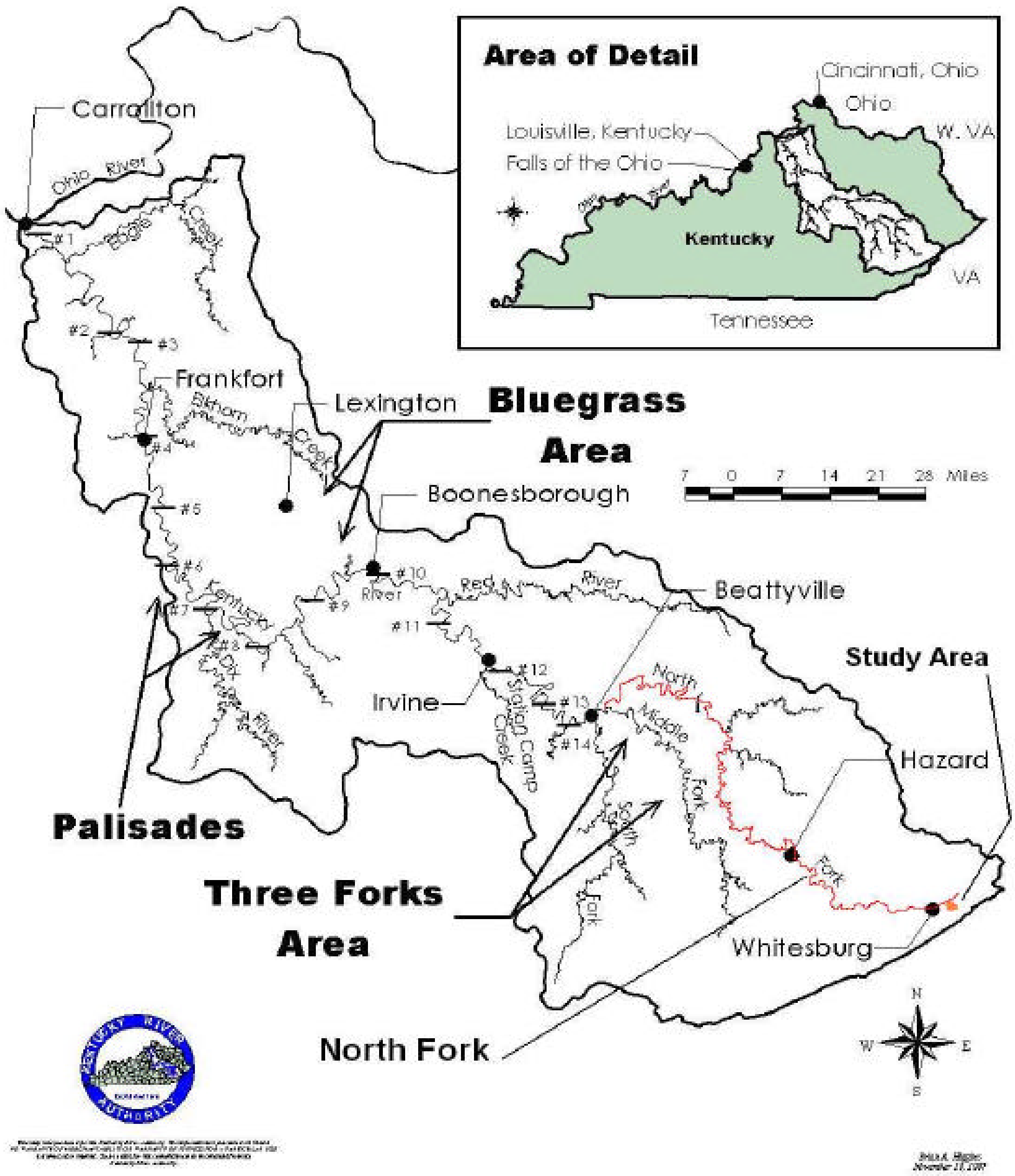



**Figure 1. "Kentucky River Basin Map",**
Modified from Brian A. Higgins, 1997, Kentucky River Authority

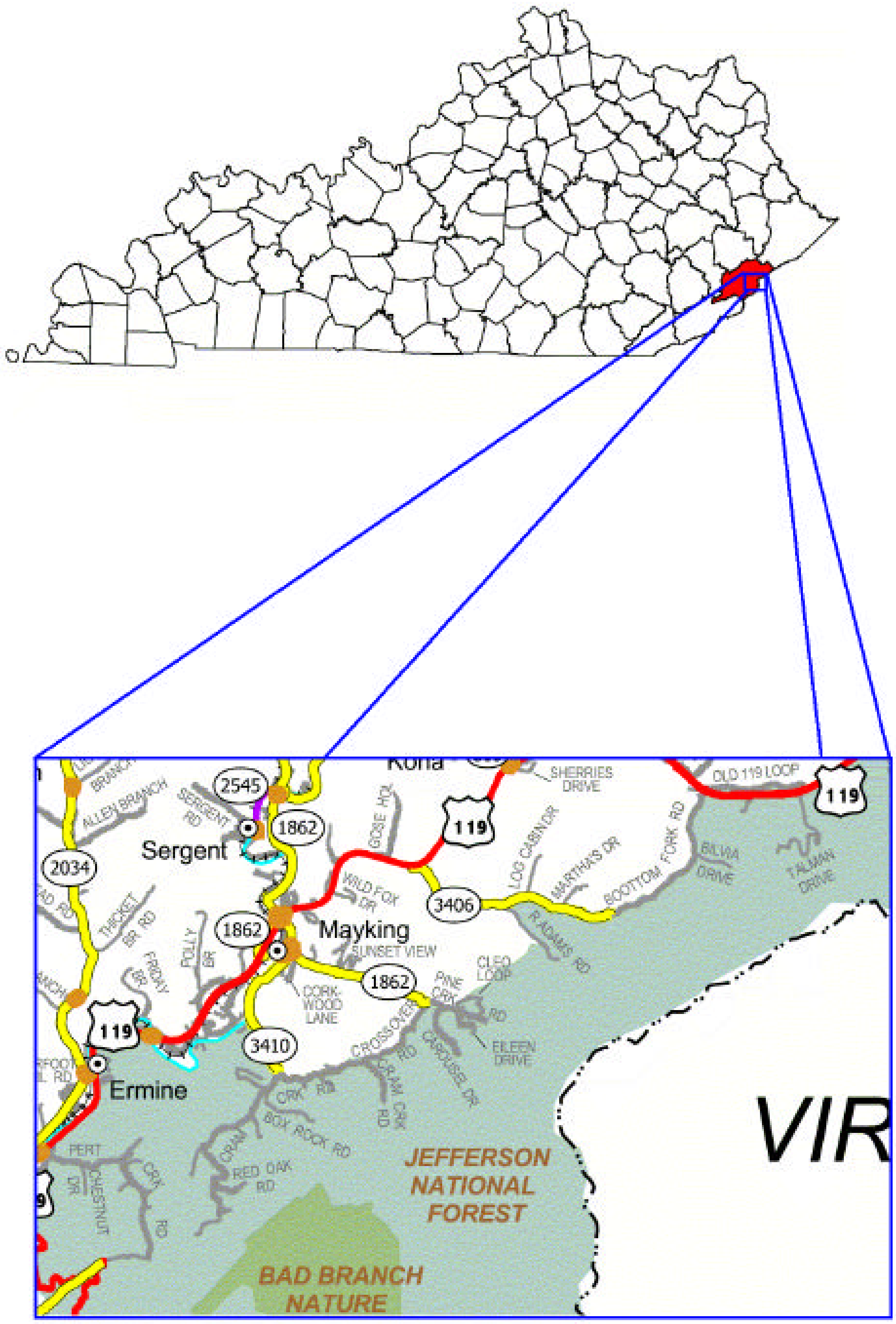



**Figure 2. Location Map for the Letcher County Study Area.**

Modified from: Kentucky Transportation Cabinet, 1999 and 2004, General Highway Maps, LETCHER COUNTY, Kentucky, Department of Highways, Division of Planning.

Field personnel inspected and sampled wells and springs (including water discharged through mine adits) used for domestic water supplies and evaluated each site for potential nonpoint source pollution sources. Informal interviews were conducted with well owners during these inspections and on-site conditions were used to educate participants about nonpoint source pollution, best management practices, and corrective measures.

As a minor part of this project, historical and current coal mining were also considered as potential sources of nonpoint source pollution (Puente et al., 1981). Two-thirds of Letcher County is owned by coal interests (MACED, 1999), and mining can have profound effects on groundwater quality and quantity. Parameters that may indicate impacts from mining include iron, manganese, pH, and sulfates.

**Previous Investigations**

Groundwater in Letcher County has been investigated by several researchers, including Mull (1965), Price et al. (1962 and 1962a), Carey et al. (1993 and 1994), and Carey and Stickney (2001). Mull (1965) inventoried 184 wells and springs (and sampled 125) used for drinking water in his “Ground-Water Resources of the Jenkins-Whitesburg Area, Kentucky”. In this study, nitrate-N, one indicator of sewage contamination occurred above the Maximum Contamination Level (MCL) of 10.0 mg/L in eight hand-dug wells. Conrad et al.(1999), looked at nitrate and nitrite in ground water statewide and Conrad et al. (1999b), looked at fluoride statewide. In two publications, Price et al. (1962, 1962a), Hopkins (1966), Kirkpatrick et al. (1963), Minns (1993), Currens (2001) and Kipp and Dinger, (1987) all present generalized geology and groundwater information for Letcher County. Carey et al. (1993, 1994) analyzed data from the statewide Kentucky Farm Bureau Ground Water Education and Testing program, including 65 sites in Letcher County. This program sampled only a limited number of constituents, including ammonia, nitrate-N, nitrite-N, chloride, sulfate, and conductivity. Ten percent of the samples statewide were also analyzed for alachlor and triazine pesticides, but none in Letcher County. This study found the Letcher County averages for ammonia, chloride, and sulfate were above the statewide averages for the same constituents. They also found the average concentrations for nitrate and nitrite in Letcher County to be below the statewide averages for these constituents.

The inherent sensitivity of groundwater to contamination has been discussed by Ray and O'dell (1993). They based their assessment on recharge, flow and dispersion, and then used this system to map groundwater sensitivity throughout the state (Ray et al. 1994). In this system, the quicker the recharge, the faster the flow and the lesser the dispersion, then the higher the sensitivity. They used a ordinal scale from 1 to 5, with low values being the least sensitive. Letcher County, including most of the study area, is underlain primarily by Pennsylvanian-age rocks, which rate a "3", or medium sensitivity. The geology of the study area is presented on 7.5-minute geologic quadrangle maps by Rice and Wolcott (1973) (Whitesburg and Flat Gap combined), and Rice (1973, 1976).

Surface water in Letcher County is discussed by Kirkpatrick et al (1963), Dyer (1983), Carey (1992), Blackburn (1998), and Carey and Morris (1996). These investigators document impacts from straight pipe discharges and coal mining, including elevated bacteria, sediment, dissolved solids, and sulfate, as well as lowered pH from acid mine drainage. Dyer (1983) concluded that increased sediment was the physical parameter primarily responsible for surface water degradation, but also concludes: "Essentially all the adverse effects of coal mining on downstream water chemistry relate either directly or indirectly to acid mine drainage produced by the oxidation of iron di-sulfides."

## Materials and Methods

The Groundwater Branch, Division of Water , managed this project and provided staffing, equipment and supplies.  The Water Quality Branch, Division of Water, advised on sampling techniques and conducted bacteriological analysis, and laboratory tests were conducted by the Division of Environmental Services .  Additional assistance was provided by the MACED North Fork Clean Water 319 project, KRA (1997), the Letcher County Fiscal Court, and the Letcher County Water and Sewer District, all of whom will receive copies of the data.

The study area was selected because of the predominant use of private wells and springs, the occurrence of numerous straight pipes discharging un-treated sewage to surface streams, and because the area is not under consideration for the installation of public water lines.  Several potential study areas in the county were rejected because of recently completed or current studies by other agencies, such as Abandoned Mine Lands, Office of Surface Mining, and the Department for Surface Mining, Reclamation and Enforcement.  The study included Pine Creek, Cram Creek, Bottom Fork and adjacent minor roads, shown on the Whitesburg, Flat Gap, Jenkins West and Mayking USGS 7.5-minute topographic quadrangle maps.

Interviews, inspections, and sampling were conducted by an experienced hydrogeologist, sometimes with an assistant.  Personnel canvassed the area door-to-door soliciting volunteers to participate in the study.  Figure 3 illustrates the distribution of participants and type of domestic water supply used by the participants.

Interviews and inspections were conducted informally to educate participants about nonpoint source pollution and potential methods to address any problems that might have been noted.  Field personnel adopted a “non-regulatory” posture during these interviews and did not issue citations for violations, but only pointed out problems and the appropriate remedial measures. For an investigation of this type, the consensus was that by using non-confrontational tactics, citizens were much more likely to participate.

Division of Water personnel inspected and sampled 80 wells and 7 springs for this study. These 87 domestic water supplies serve an estimated 350 persons. Thirty-one wells appeared to meet current water well construction standards. Forty wells did not meet current standards: 31 wells had buried wellheads, a once common well completion practice that is not allowed by current regulation; nine wells did not meet standards for other reasons, such as pit construction, casing not extending above ground level, improper seal, or the lack of a well cap. Nine wells were shallow, hand-dug wells. In addition, nine bacteria samples were collected from two streams in the study area.

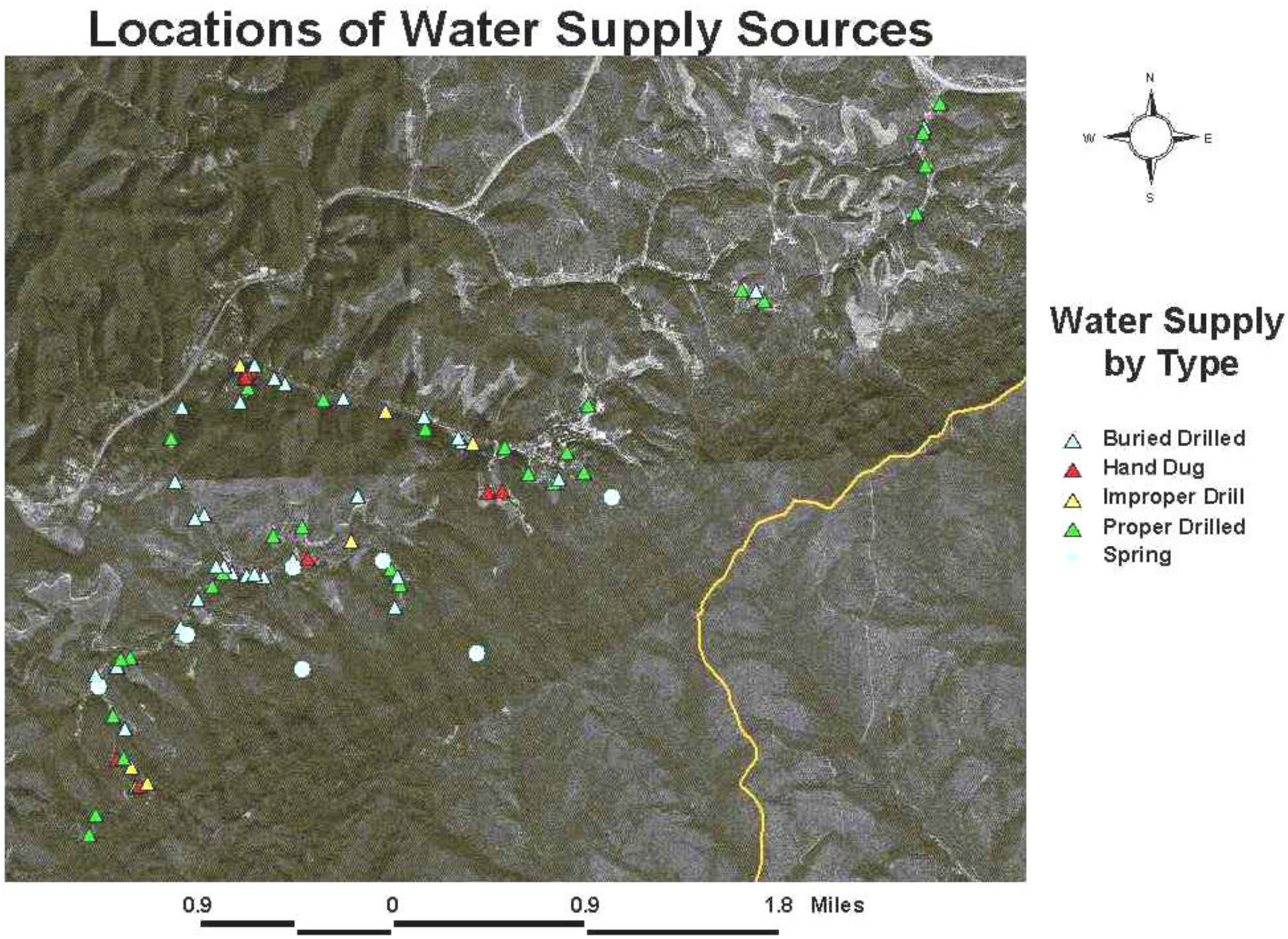



**Figure 3. Locations of water supply sources used in this study**

The seven springs included water discharged through mine adits, two of which provide sufficient water to supply several households. Three households piped limestone spring water more than 1000 feet to their homes. Several homes along a side spur of Pine Creek Rd. reported that they obtained their water from the adjacent surface stream. Field personnel did not collect water samples from this stream reach.

The Division of Water provided participants with material (Appendix C) on nonpoint source pollution, water wells and other topics (if applicable). These materials included: Generic Groundwater Protection Plans (GPP) for Domestic Well Owners and Residential Septic Systems; various literature regarding nonpoint source pollution and well maintenance; a completed inspection form for their well or spring; a nonpoint source inventory for their property; field screening test results; and, if applicable, information on pesticides, erosion control, on-site disposal systems, and solid waste management and disposal.

In addition to well and spring inspections, distribution systems at each site were also inspected. This helped determine proper sampling points to ensure that samples were representative of groundwater, and not distribution system artifacts. The on-site screening test (CHEMetrics, 2000) included nitrate-N, nitrite-N, ammonia-N, detergents (ionic surfactants), iron, manganese, and phosphate. Copies of the *Field Analytical Data Screening* and *Field Inspection Check Off Sheets* are in Appendix C.

On-site screening is quick and cost-effective and allowed the inspectors to integrate the results into the inspection and interview. Field results of one half or more of the drinking water Maximum Contaminant Level (MCL) were verified by laboratory analysis. Field measurements included temperature, pH, and conductivity using handheld meters calibrated according to the manufacturer's specifications and Division of Water Standard Operating Procedures (2003).

Late in the study, personnel performed pre- and post-treatment analyses for soluble iron and manganese at a few residences. The testing of treated and untreated samples in the field examined the effectiveness of these domestic treatment systems at removing iron and manganese. This pre and post treatment testing showed the water quality at the tap is often much different from the raw water quality at the well.

After the initial interview and sampling, the project manager sent postcards (Appendix C) offering each participant a bacteriological evaluation of their water, and 22 well and spring owners accepted. This sampling included total, fecal, and *E-coli* bacteria tests. Samples were also collected for caffeine (and metabolites). Caffeine samples were analyzed only for those sites detecting high levels of bacteria.

Bacteria samples were collected at 20 wells, one spring and nine stream sites from September 10-12, 2001. In order to meet the six-hour holding time for bacteria, samples were analyzed at the Division of Water's Hazard regional office, which is only 25 miles from the study area.

The hydrogeologist made field observations to determine the potential for various nonpoint source pollution at each well or spring. Since well and plumbing system artifacts can sometimes produce nonpoint source indicators, a thorough well and plumbing system inspection was made to eliminate any potential problems. Improper well and plumbing system maintenance can result in water quality problems at the tap even thought the groundwater quality is just fine.

Each participant received copies of the *Field Analytical Data Screening* and *Field Inspection Check Off Sheets*. The hydrogeologist discussed the field analytical results with each owner, including potential causes, concerns, and suggested corrective actions for any problems discovered during the inspection.

**Sample Methods**

Field tests manufactured by CHEMetrics and EMD Inc. were used in this study. These tests employ colorimetric comparison to determine concentration levels, and are summarized in Table 1. Samples collected for laboratory confirmation were analyzed according to departmental and USGS protocols, USGS (1983, 1984), Claassen (1982). Conductivity, pH and temperature were collected with field meters calibrated and operated according to the manufacturer's recommendations.

Bacteria were analyzed using Colilert® and Quanti-Tray/2000® systems. Some samples collected during bacteria sampling were also analyzed for caffeine and its metabolites, 1,7 -dimethylxanthine, 7 - methylxanthine, and 1- methylxanthine. Because of limited laboratory capacity, only 16 samples (six wells, one spring and nine surface water) from sites with the most significant bacterial contamination were analyzed for caffeine and its metabolites.

| Parameter | Test Method | Test Range | Minimum Detection Limit MDL | Web Link to more details |
|---|---|---|---|---|
| Nitrate – N | Colorimetric method from CHEMetrics (VACUettes® Cadmium Reduction/Azo Dye Formation Method) | 0 – 25 mg/L (low)<br>25 – 125 mg/L (high) | 2.5 mg/L | http://www.chemetrics.com/Products/Nitrate.htm |
| Nitrite – N | Colorimetric method from CHEMetrics (VACUettes® Azo Dye Formation Method) | 0 – 10 mg/L (low)<br>10 – 50 mg/L (high) | 1.25 mg/L | http://www.chemetrics.com/Products/Nitrite.htm |
| Ammonia – N | Colorimetric method from CHEMetrics (CHEMet® Nesslerization Method) | 0 – 1 mg/L (low)<br>1 – 10 mg/L (high) | 0.05 mg/L | http://www.chemetrics.com/Products/Ammonia.htm |
| Phosphate – PO4 (Ortho – reactive) | Colorimetric method from CHEMetrics (CHEMet® Molybdenum Blue/Stannous Chloride Method) | 0 – 1 mg/L (low)<br>1 – 10 mg/L (high) | 1.25 mg/L | http://www.chemetrics.com/Products/Phosphat.htm |
| Detergents-Anionic Surfactants | Colorimetric method from CHEMetrics (Methylene Blue Active Substances (Mbas) Method) | 0 – 3 mg/L | 0.125 mg/L | http://www.chemetrics.com/Products/Deterg.htm |
| Soluble Iron | Colorimetric method from CHEMetrics (CHEMet® 1, 10 Phenanthroline Method) | 0 – 1 mg/L (low)<br>1 – 10 mg/L (high) | 0.05 mg/L | http://www.chemetrics.com/Products/IronTS.htm |
| Soluble Manganese | Colorimetric method from CHEMetrics (CHEMet® Periodate Method) | 0 – 2 mg/L | 0.15 mg/L | http://www.chemetrics.com/Products/Mangan.htm |
| Nitrate – $NO_3^-$ | Colorimetric Test Strip method from EMD, Inc. | 0-500 mg/L | 10 mg/L | http://www.emdchemicals.com/analytics/literature/displaylit.asp?location=ar&litfile=311021_Nitrate_Test.htm |
| Nitrite – $NO_2^-$ | Colorimetric Test Strip method from EMD, Inc. | 0-80 mg/L | 2 mg/L | http://www.emdchemicals.com/analytics/literature/displaylit.asp?location=ar&litfile=311023_Nitrite_Test_2.htm |

**Table 1. Field analytical methods, test ranges, Minimum Detection Limits and links.**

## Quality Assurance/Quality Control (QA/QC)

QA/QC plans (Appendix B) were approved by the Division of Water and the Nonpoint Source Section prior to any fieldwork, and all activities conducted were consistent with these plans.

Field test results equal to or above one-half the primary drinking water standard were confirmed via laboratory analysis by the Division of Environmental Services. Additional laboratory samples were collected from at least one well for each sampling event. Confirmatory sample testing at the laboratory was sometimes modified, dependent upon the availability of the lab, but usually included: Chloride, fluoride; nitrate-N; nitrite-N; sulfate, ortho-P; alkalinity; conductivity; pH; total suspended solids (TSS); total dissolved solids (TDS); ammonia-N; total kjeldahl nitrogen (TKN or $NH_3$ plus organic bound–N); total organic carbon (TOC); total phosphorus; and total metals by Inductively Coupled Plasma (ICP) Atomic Emission Spectrometer methodology. A standard DOW Groundwater Branch chain-of-custody form (Appendix C) accompanied each sample.

## Results and Discussion

Tabulated results for all field and laboratory tests can be found in Appendix D. Kentucky lacks groundwater quality standards and water quality for private systems is not regulated. Therefore, most of the raw water quality parameters collected for this study are compared to the limits established by the USEPA for public water systems supplying drinking water to the public. For parameters with no established USEPA limits, other standards, as noted in Table 2, were applied.

**Table 2. Parameters and Standards**

| ***Parameter*** | ***Standard*** | ***Source/Discussion*** |
|---|---|---|
| Nitrate-N | 10.0 mg/L | MCL |
| Nitrite-N | 1.0 mg/L | MCL |
| Ammonia-N | 0.110 mg/L | DEP |
| Iron | 0.3 mg/L | SMCL |
| Manganese | 0.05 mg/L | SMCL |
| Conductivity | 800 µmho | No MCL, SMCL or HA; this corresponds to about the SMCL of 500 mg/L TDS |
| PH | 6.5 to 8.5 S. U. | SMCL |
| Ortho-P | 0.04 mg/L | No MCL, SMCL or HA; Texas surface water standard |
| Detergents-Anionic Surfactants | None | No natural sources |
| Caffeine/metabolites | None | No natural sources |
| Bacteria | Zero* | *Explained in text below |

The USEPA (2004) defines three types of drinking water standards: Maximum Contaminant Levels, Secondary Drinking Water Regulations and Health Advisories. These, and other related terms, are defined below.

**Maximum Contaminant Level (MCL)** is "the highest level of a contaminant that is allowed in drinking water." MCLs are legally enforceable limits applied to "finished" public drinking water based on various risk levels, ability to treat and other cost considerations. MCL standards are health-based and are derived from calculations based on adult lifetime exposure, with drinking water as the only pathway of concern. These standards are also based upon other considerations, including the efficacy and cost of treatment. In addition, some parameters have a **Maximum Contaminant Level Goal (MCLG)** which is “A non-enforceable health goal which is set a level at which no known or anticipated adverse effect on the health of persons occurs and which allows a margin of safety.”

**Secondary Drinking Water Regulations (SDWR)** are defined as ". . . non-enforceable Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water." In common usage, this is often referred to as **S**econdary **M**aximum **C**ontaminant **L**evel (**SMCL**) and this usage has been adopted for this report.

**Health Advisory (HA)** is ". . . an estimate of acceptable drinking water levels for a chemical substance based on health effects information; a Health Advisory is not a legally enforceable Federal standard, but serves as technical guidance to assist Federal, state and local officials." Again, reflecting common usage, this term has been modified slightly and is referred to in this document as the **H**ealth **A**dvisory **L**evel (**HAL**).

**Treatment Technique (TT)** is "A required process intended to reduce the level of a contaminant in drinking water." Public water systems are required to control the corrosiveness of their water, and if more than 10% of tap water samples exceed the **Action Level (AL)**, then water systems must take additional action.

**Nitrate/Nitrite**

The nitrogen cycle is one of the most important nutrient cycles found in nature. In addition to its natural occurrence, nitrate and nitrite also occur from several anthropogenic sources, including sewage, fertilizers, explosives and the combustion of fossil fuels, which releases these compounds into the atmosphere where they become a component of "acid rain".

Nitrate is very soluble and can percolate downward to the groundwater, where it can become a health concern at elevated levels. According to the USEPA (1999a), exposure to nitrate in young children can interfere with the oxygen carrying capacity of the blood in a condition referred to as “Blue Baby Syndrome” or methemogoblinemia. Therefore, the USEPA established an MCL of 10 mg/L for nitrate-N and 1 mg/L for nitrite-N to prevent this condition. At present, there is inadequate evidence to determine whether lifetime exposure to high levels of nitrates or nitrites have the potential to cause cancer. However, chronic exposure to high levels of nitrate/nitrite is known to cause diuresis, increased starchy deposits and hemorrhaging of the spleen in some people (USEPA, 1999a.)

Three separate domestic water supplies contained nitrate above the MDL, but no domestic water supplies contained nitrate concentrations near the MCL of 10 mg/L. No trends or obvious sources of the nitrate were found during the review of the data. It is unclear whether the low nitrate concentrations are natural or the result of NPS pollution.

Nitrite was detected above its MCL of 1.0 mg/L in one hand-dug well. Attempts to re-sample this well for laboratory verification were unsuccessful.

Well water with high iron levels has a coloration that can mimic the color of low level detections of nitrate and nitrite, this resulted in nitrate/nitrite levels being recorded when it was not present. This problem with the colorimetric test produced a poor correlation with the lab verification samples. The nitrate/nitrite test strips did not produce false positives in iron rich water. The test strips seem to be an inexpensive and adequately accurate field-screening tool for determining the presence of potential nonpoint source pollution. The speed and ease of use of the test strips allows field personnel to conduct targeted biased sampling, track contamination to a source, and make decisions in the field without waiting for the lab analyses. The strips are inexpensive and therefore can help minimize costly laboratory analysis. As result of this study, DEP emergency response personnel used the nitrate/nitrite test strips to monitor and track the source of a fertilizer spill.

**Ammonia**

Ammonia ($NH_3$) occurs naturally in the environment, primarily from the decay of plants and animal waste. The principal sources of ammonia in groundwater are ammonia-based fertilizers and human and animal waste. No drinking water standards exist for ammonia; however, the proposed DEP risk-based limit for groundwater is 0.110 mg/L.

Ammonia was detected in 16 of 83 sites (19.3%) sampled, and values ranged from 0.5 mg/L to 6.0 mg/L. The highest value was found in a well meeting current construction standards. Ammonia was not detected in any of the springs included in the study.

Because agricultural application and confined-feeding operations are not potential sources of ammonia within the study area, the interpretation is that failing septic systems or straight pipe disposal of human waste is responsible for the locally elevated levels of ammonia seen in this study.

**Phosphate**

Phosphate ($PO_4^{-3}$) is naturally occurring in soils and in some rocks of Kentucky, but is not prevalent in the soils and rocks of the project area. Elevated levels of phosphate can be indicative of contamination from sewage or the over-application of fertilizer.

Phosphate occurs in three different forms in the environment: organophosphates are found in some pesticides and in living organisms, both plants and animals; polyphosphates are common in detergents; and orthophosphate is a common constituent of sewage (The Fertilizer Institute, 2002). In water, these three different forms of phosphate break down over time to form orthophosphate, and the Chemetrics field test kit for phosphate measures this form. No drinking water standards exist for phosphate or orthophosphate, but USEPA (1999b, 2000) studies indicate that eutrophication in surface streams can be controlled by limiting maximum total phosphorus concentrations to 0.1 mg/L.

Surface water requires some phosphate to stimulate the growth of plankton and aquatic plants that provide food for fish. However, excess phosphate contributes to eutrophication or over-fertilization, a situation in which algae and other aquatic plants grow rapidly, choking waterways and reducing oxygen levels which in turn kills aquatic life (Univ. of Georgia, 2002).

Orthophosphate was found in only 5.7% of the samples, and detections ranged from 2.5 mg/L to 5.0 mg/L $PO_4^{3-}$, using a MDL of 2.5 mg/L, which is well above the levels at which surface waters could be impaired. Because of this relatively high detection level compared to the low levels that can influence groundwater quality, no conclusions regarding the possible impact of phosphate on groundwater in the project area can be made.

**Detergents-Anionic Surfactants**

Detergents-Anionic surfactants are a good indicator of domestic wastewater contamination since they are components of household detergents and soaps. Surfactants are also found in some pesticides and in products used in well drilling (particularly in oil and gas wells) to facilitate removal of cuttings.

Four samples (4.6%), all from drilled wells deeper than sixty feet, detected anionic surfactants above the MDL of 0.125 mg/L. The exact sources for these detections are unknown, but they may come from oil and gas drilling or infiltration from polluted the surface streams. No correlations could be made to other parameters included in this study. Nonpoint source pollution impacts from detergents appear to be minimal at this time.

Logistics and holding times prevented lab verification, and therefore the effectiveness of these field tests was not determined.

**Soluble Metals**

The Pennsylvanian-age rocks of eastern Kentucky contain enough iron locally to have supported historical iron mining. These rocks also contain significant quantities of manganese. Chemical and biological reactions, in particular the growth of iron bacteria, in aquifers can release iron and manganese into groundwater. Iron concentrations above 1.0 mg/L and manganese 0.1 mg/L can impart a foul taste to water and cause staining of laundry and porcelain fixtures. Routine well disinfection through chlorination can inhibit the development of iron-related bacteria and minimize the gradual increase of iron and/or manganese in the water. Iron and manganese have SMCLs of 0.3 mg/L and 0.05 mg/L, respectively.

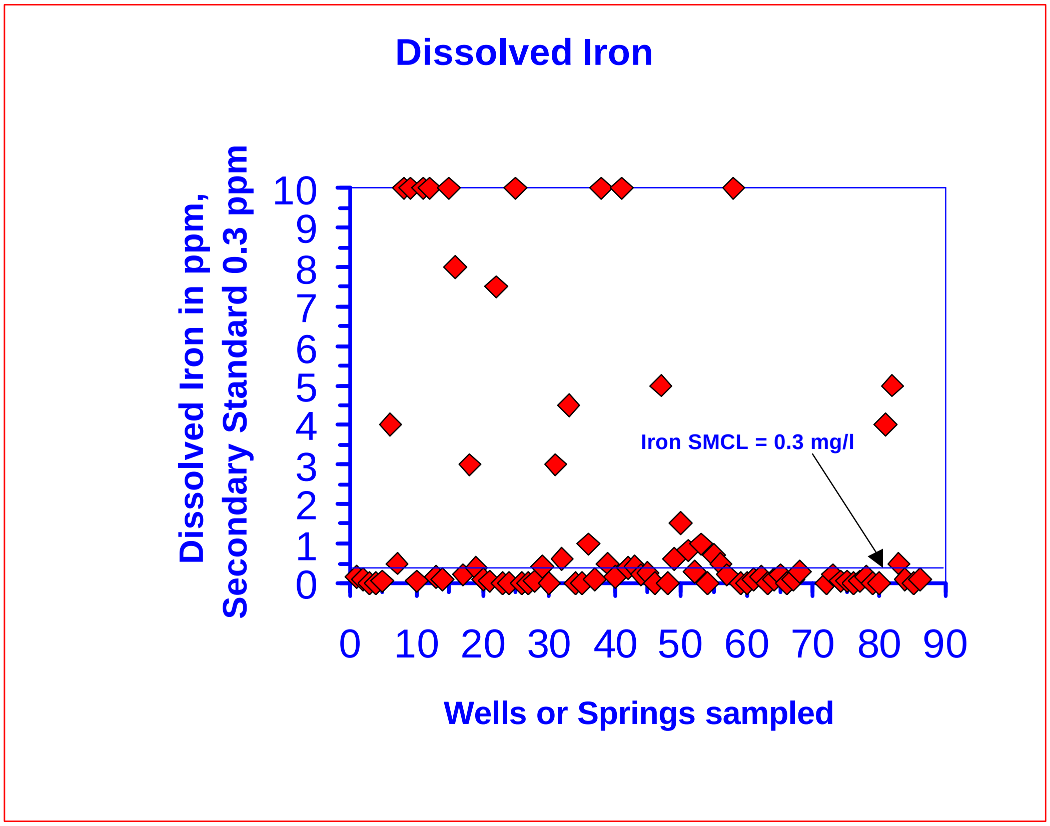
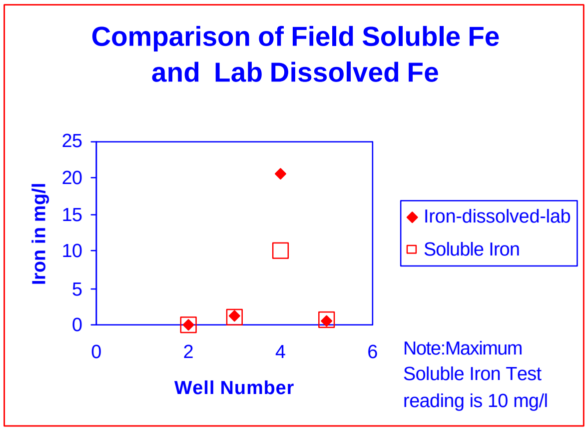



**Figure 4. Iron Results from the Complete Study.**

Note: field test only measured to 10 ppm (mg/L), so results of 10 ppm indicate 10 ppm or above.

Iron (Figure 4) was detected at or above its SMCL in 33 of 81 samples (40.7%). Wells with buried wellheads were most likely to have high levels of iron, with 17 of 28 meeting or exceeding the SMCL of 0.03 mg/L. Iron was not detected above SMCL in any spring. Field personnel noted iron and manganese removal is the primary purpose of all the domestic treatment systems observed.

Iron concentrations were plotted against depth (Figure 6) to see if there were any significant correlation. Most high iron concentrations occur in wells between 50 and 150 feet in depth, which is consistent with observations reported by drillers in eastern Kentucky who commonly observe that the first bedrock aquifer usually has the highest iron. Shallow soil water wells and wells cased down to a deeper aquifer are generally much lower in iron.



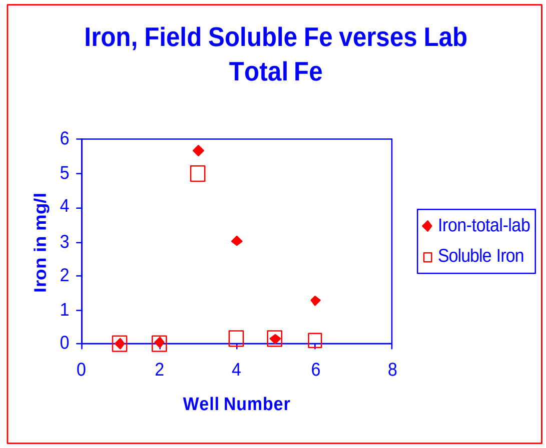




**Figure 5. Iron Field Results vs. Laboratory Results**

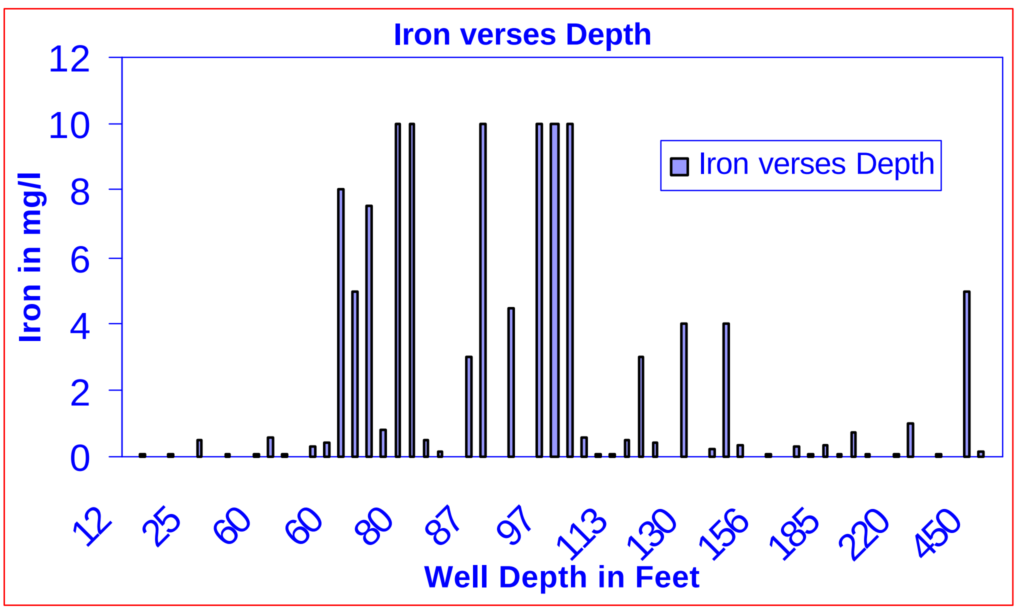



**Figure 6. Iron Levels verses Well Depths**

The MDL of 0.15 mg/L for the manganese field test, which is three times more than the SMCL of 0.05 mg/L, limits the usefulness of this test for drinking water. The reddish comparison color for this test is easily confused with oxidized iron in the water, which tends to mask low-level readings. Because of these factors, this test is more suitable for industrial discharge testing than evaluation of drinking water supplies. Seven wells and one spring had manganese concentrations at or above the MDL for this method. One well had manganese at 12.2 mg/L (244 times higher than the SMCL) before treatment. Field staff evaluated the effectiveness of domestic treatment systems for manganese and iron removal at a few homes by testing before and after treatment (Figure 7).

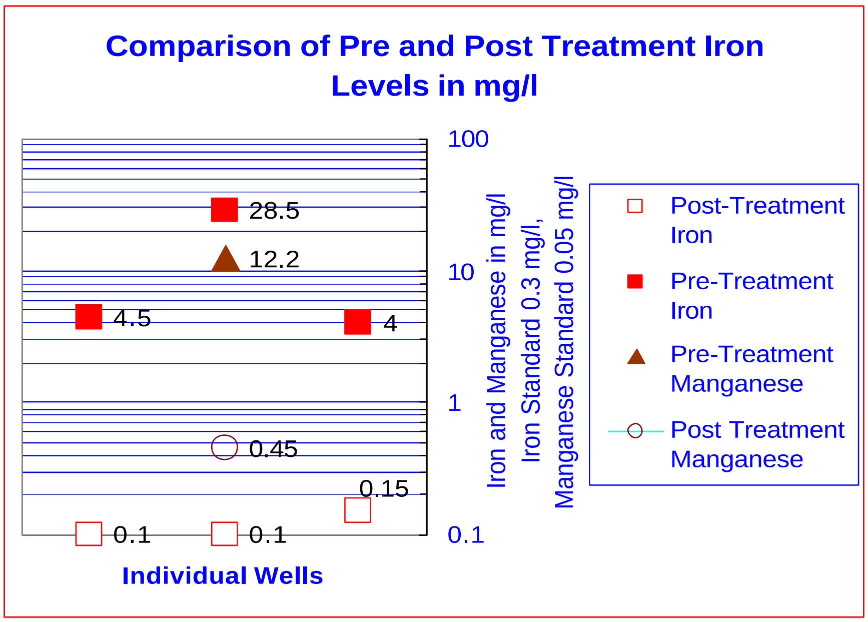



**Figure 7. Pre and Post Treatment for Iron and Manganese**

## Conductivity

Conductivity measures water's ability to transmit an electrical current. The standard units for conductivity are microsiemens per centimeter, or mS/cm. Conductivity measures a property of water, rather than a quantity and is an indirect measurement of the amount of dissolved material in water. In general, a conductivity reading of 800 mS/cm is approximately equal to the SMCL for Total Dissolved Solids (TDS) of 500 mg/L.

Water with very low or very high conductivity can be corrosive and aggressive. Low conductivity water is a very good solvent and can dissolve metals from the plumbing. High conductivity water is often times high in salts that can be corrosive to metals. In either case, corrosion can leach lead and other heavy metals into water used for consumption. Formations with highly soluble aquifer matrices and long residence times (as found in deeper formations) generally have higher conductivity waters.

Conductivity ranged from 57.4 (mS/cm) to 2400 mS/cm with an average of 468 mS/cm. The lowest conductivities were generally at higher elevations on Pine Mountain in shallow wells. The highest conductivity was found in deeper drilled wells near the North Fork of the Kentucky River. Salty groundwater is known to occur at shallow depths in valley wells in eastern Kentucky and most likely represent naturally occurring brines. Both well owners with conductivity readings around 2000 mS/cm reported their water tasted "salty".

**pH**

pH is the negative log of the concentration of the hydronium ion and is essentially a measure of the relative acidity or alkalinity of water. The units of pH are dimension less, “Standard Units” or “SU”, and the scale measures from 0 to 14. In this system, 7 represents neutral pH and values less than 7 are more acidic; values greater than 7 are more alkaline. The relative acidity/alkalinity of water is important in regard to water quality because this affects the corrosiveness of the water and its ability to dissolve contaminants such as heavy metals, in particular lead and copper, and also because pH affects the taste of the water.

The pH range of normal aquatic systems is between 6.5 and 8.0. Low pH levels can indicate nonpoint source impacts from coal mining or other mineral extraction processes. High pH values for groundwater may indicate nonpoint source impacts to groundwater from brine intrusion from current or former oil and gas exploration and development activities. pH has an SMCL range of 6.5 to 8.5 S.U.

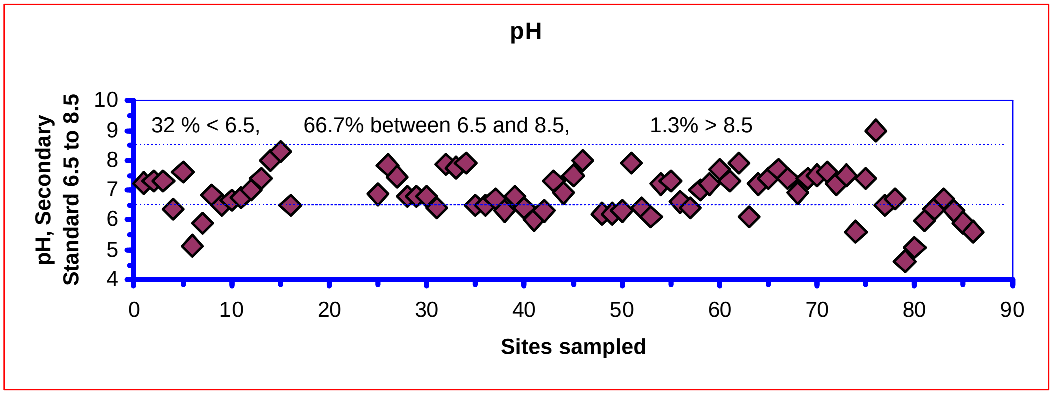



**Figure 8. pH data.**

In this study, 66.3% of the samples were within the SMCL range of 6.5 to 8.5. Approximately one-third of the wells were below 6.5; only one well exceeded the standard range.

## Bacteria

Three types of bacterial analyses were conducted for this study: total coliform, fecal coliform and *Escherichi coli*, abbreviated *E. coli.*

"Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being *Escherichia coli*. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals" (RAMP, 1986).

Bacteria are ubiquitous in soils and in the environment in general, Cullimore, (1993 and 1996). Public water supplies use total coliform bacteria analysis as an inexpensive and simple test to determine if the amount of disinfectant used is sufficient. Total coliform bacteria are a surrogate parameter and the assumption is that if total coliform bacteria are not present, then more harmful bacteria, pathogens and viruses are also not present. County health departments commonly use this test to evaluate domestic water well quality. Because they are ubiquitous, total coliform bacteria alone are not a fail-safe indicator of nonpoint source contamination. However, the presence of fecal or E. coli bacteria are reliable indicators of contamination from human or animal waste, which is a health risk through either ingestion or contact. Because E. coli tend to die quickly and do not multiply in groundwater, their detection indicates a direct connection to a contaminated source or possibly a sampling problem.

Publicly supplied drinking water has an MCLG of zero for total coliforms and the standard states further that "No more than 5.0% samples total coliform-positive in a month. Every sample that has total coliforms must be analyzed for fecal coliforms; no fecal coliforms are allowed." Because many participants in this study use their wells or springs only for bathing, contaminated water is also a concern because contact through the eyes, ears, nose, throat and cuts provides pathways for bacteria to enter the body. Kentucky's primary surface water standards for full body contact recreation, or swimming, provide appropriate values to compare contact through bathing. This standard is not more than 200 colonies/100 ml for fecal coliform and not more than 130 colonies/100 ml for *E. coli*.

Because of the short holding time for bacteria of six hours, samples had to be collected during the day when home-owners were not at home. Unfortunately, this lack of access to more suitable sampling sites resulted in the collection of many samples from outside, freeze proof hydrants, which by their design tend to harbor bacteria. Further, these faucets are often neglected during routine well and system disinfection. However, wells sampled from freeze proof hydrants were purged for at least five minutes to flush any residual bacteria from these fixtures and lines.

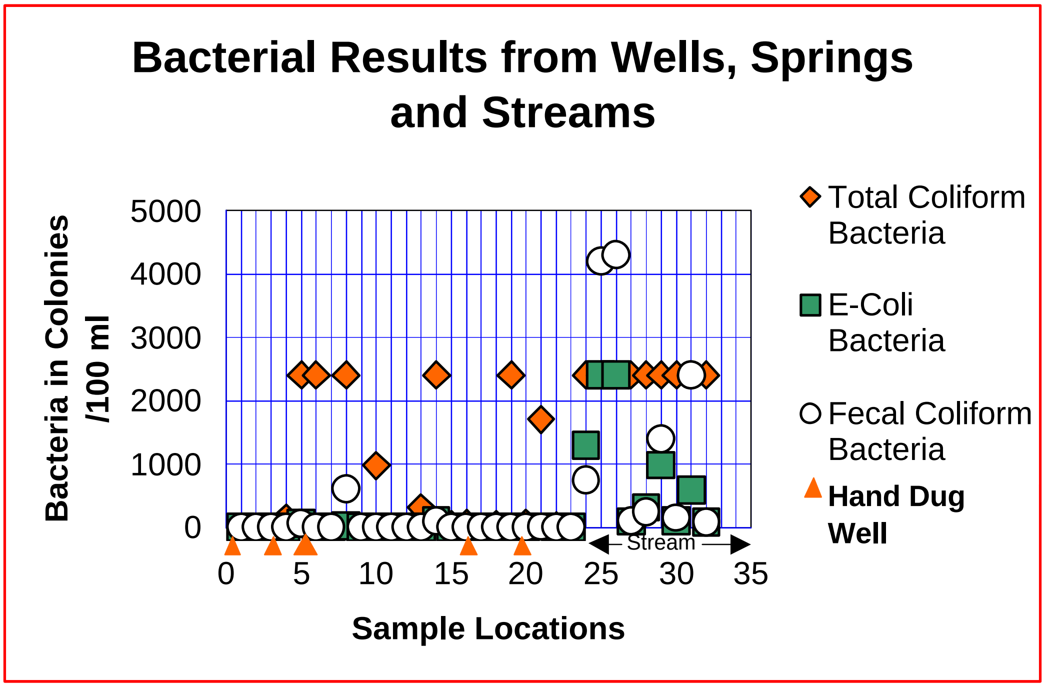



**Figure 9. Bacterial Results from Wells, Springs and Streams**

Bacterial results are shown graphically in Figure 10 above, and in tabular form in Appendix D, Tables 2 & 3. Total coliform bacteria ranged from zero colonies/100 ml to >2400 colonies/100 ml. Sixteen of the 21 wells tested had total coliform bacteria present. As noted above, the detection of total coliform bacteria without fecal coliform or *E-coli* bacteria does not necessarily indicate NPS contamination.

Fecal coliform bacteria ranged from zero colonies/100 ml to 610 colonies/100 ml, and were found in three hand-dug wells and one drilled well. All sites detecting fecal coliform also detected E. coli.

## Stream Bacteria Sampling

Field personnel collected stream bacteria samples along Pine Creek and Cram Creek (Figure 8) for comparison to the well data as shown in Figure 9. The data are also shown in Table 6 in Appendix D.

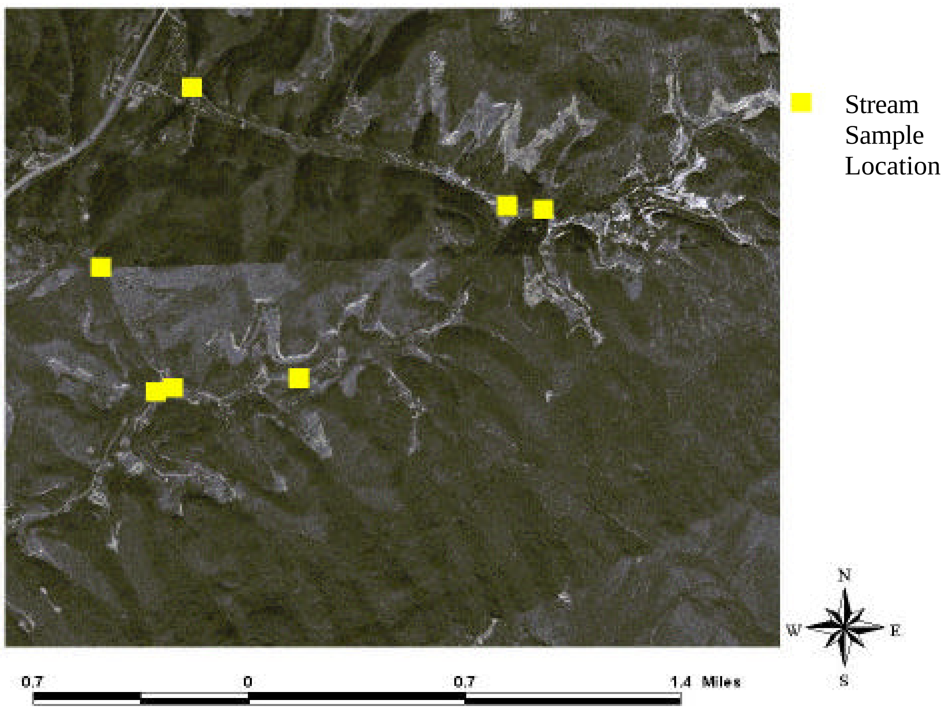



**Figure 10. Locations of Stream Sample Collection Sites**

Ground and surface water bacteria results show no correlation. The streams appear to be gaining streams, which may prevent stream water contaminated by straight pipe discharges from infiltrating into the nearby shallow groundwater in most places. One possible exception, a 12-foot deep hand-dug well, that reportedly produces enough water to fill an in-ground pool over night, which indicates a likely direct connection between the stream and the well. This well contained elevated total coliform bacteria, fecal coliform bacteria and *E-coli* bacteria along with nitrite, caffeine and caffeine breakdown products.

## Caffeine and Metabolites

Because it is not naturally occurring in most areas, caffeine and its metabolites are good indicators of contamination from human waste (USGS, 1995; Ralof, 1998; Pearson, 2004).

Caffeine and/or metabolites were detected in six of 16 samples, as shown in Figure 11, which plots bacteria and caffeine results on a log scale, showing the high variability of bacteria, but the relatively low variability of caffeine. Two wells (of five sampled) detected caffeine or metabolites: one 12-foot deep hand-dug well and one 120-foot deep drilled well that appeared to be properly constructed. The hand-dug well was also positive for total, fecal and E. coli bacteria, but the drilled well was positive for only total coliform bacteria.

Nine surface water samples were analyzed for caffeine and metabolites, five on Cram Creek and four on Pine Creek. Four (44.4%) were positive for caffeine and/or metabolites, one

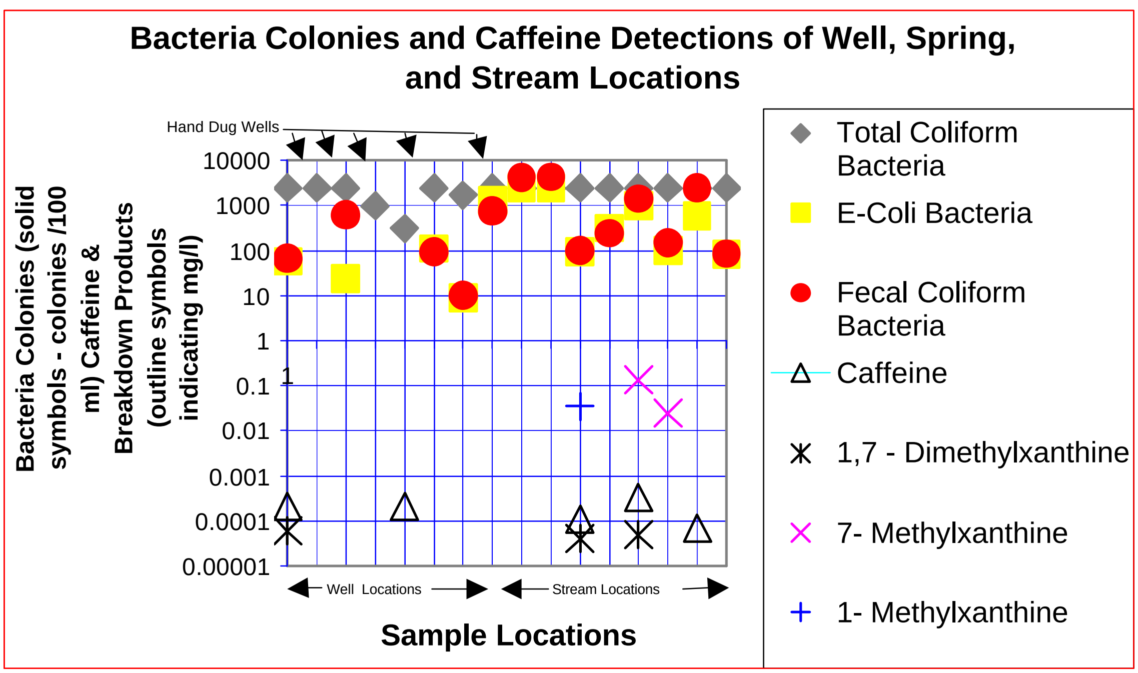



**Figure 11. Relationship of bacteria and caffeine results for wells and streams.**

on Cram Creek and three on Pine Creek. With limited data, no positive correlation between the occurrence of bacteria and caffeine could be established.

Because caffeine is only derived from anthropogenic sources, through waste discharged through straight pipes or from septic systems, its occurrence indicates that groundwater in the study area has been impacted and is threatened by these discharges.

**Figure 12. Improper storage of household chemicals around a hand-dug well.**

## Conclusions and Recommendations

No pervasive nonpoint source pollution of groundwater was found in this study. However, shallow groundwater locally tests positive for total, fecal and E. coli bacteria, probably because of straight pipe discharges or failing septic systems. Total, fecal, and *E-coli* bacteria were significantly higher in hand-dug wells than in drilled wells. Many of the well problems encountered in this study result from improper construction and maintenance of wells and distribution systems, improper set-backs from possible contaminant sources and poor management or "house-keeping" around the well (Figure 13). Participants were counseled in all relevant topics, and provided with printed information, and this assistance to eighty-seven groundwater users was a valuable part of this project. Residents were very appreciative of this informal, one-on-one, "non-compliance" approach and one participant replaced her shallow, poorly constructed and easily contaminated well with a deeper drilled well meeting current construction standards as a result of this study. Little impact from other nonpoint sources was noted, including from nitrate, nitrite, phosphate, iron, manganese or altered pH from septic systems or coal mining. Streams in the area are gaining, rather than losing, and therefore wells up gradient of these streams are generally not threatened by surface water pollution. Agricultural activity and residential use of lawn and garden chemicals is very limited in the area and represent minimal nonpoint source pollution threats to groundwater. Other threats to groundwater locally include improper disposal of domestic trash and motor oil, animal waste and coal mining.

In general, properly constructed and maintained wells in the study area produce adequate water that is easily treatable by standard water treatment devices. Substandard wells not meeting current construction standards, and especially shallow, easily contaminated hand-dug wells, should be replaced with deeper, properly installed wells. Residents should consider taking advantage of The Affordable Drinking Water Act of 2001, an amendment of the Federal farm bill, which authorizes low interest loans to low-to-moderate-income households to help owners install, refurbish or service water well systems.

The relatively good quality of the shallow groundwater emphasizes the need for quality, well planned and designed septic systems to replace the straight pipe disposal of septic tank effluent. Sites should be fully evaluated and site-specific waste disposal systems should be installed and maintained. Innovative onsite septic systems, including large cluster, mound/peat mound, and modular systems (Equaris of Minnesota, Inc., 2002), have been installed in other areas of Letcher County, and these should be considered for the project area.

The extension of sewer lines into this area or the installation of package sewage treatment plants at the mouths of hollows with significant development should also be considered.

Some residents claim that coal mining has negatively impacted their water quality and quantity. Water quantity was outside the scope of this investigation; however, for the limited number of parameters included in this study, no impacts to water quality from coal mining were found.

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# Appendix A. Financial and Administrative Closeout

## Workplan Outputs

**Milestones:**

| | Milestone<br><br>Completion | Expected Beginning<br><br>Date | Completed<br><br>Date |
|---|---|---|---|
| 1. | QA/QC Plan Approved | 04/98 | 04/98 |
| 2. | Submit material to NPS Section for review and approval prior to distribution | 04/98 | 07/98 |
| 3. | Preliminary work - identify areas where groundwater is used as source of domestic drinking water and priority areas for water and sewer expansion | 04/98 | 07/98 |
| 4. | Start site inspections, initial sampling and on-site education re: NPS pollution | 07/98 | 10/98 |
| 5. | Bacteriological sampling round and follow up of on-site NPS education efforts | 09/98 | 09/01 |
| 6. | Annual Report | 09/98 | 09/98 |
| 7. | Resampling at sites of concern. | 10/98 | 11/98 |
| 8. | Evaluate problem groundwater resource areas from data and observations | 11/98 | 01/99 |
| 9. | Distribute results to participants along with explanation | | |

| | | | |
|---|---|---|---|
| | and relevant NPS information | 01/99 | 03/99 |
| 10. | Share information with MACED and Letcher County Water and Sewer District | 07/98 | 03/99 |
| 11. | Annual Report | 09/99 | 09/99 |
| 12. | Prepare summary report | 01/99 | 01/04 |
| 13. | Present summary report and recommendations to the Letcher County Fiscal Court and the Letcher Count Water and Sewer District | 04/99 | 02/04 |
| 14. | Close out grant activities | 05/99 | 05/04 |
| 15. | Final and close-out reports submitted to Division of Water | 05/99 | 05/99 |

**Project Budget:**

**Budget Summary**

| Budget Categories | BMP Implementation | Project Management | Public Education | Monitoring | Technical Assistance | Other | Total |
|---|---|---|---|---|---|---|---|
| Personnel | | | | $116,365 | | | $116,365 |
| Supplies | | | | | | | |
| Equipment | | | | | | | |
| Travel | | | | | | | |
| Contractual | | | | | | | |
| Operating Costs | | | | | | | |
| Other | | | | | | | |
| **TOTAL** | | | | **$116,365** | | | **$116,365** |

**Detailed Budget**

| Budget Categories | Section 319(h) | Non-Federal Match | Total | Final Expenditures |
|---|---|---|---|---|
| Personnel | $69,819 | $46,546 | $116,365 | $116,365 |
| Supplies | | | | |
| Equipment | | | | |
| Travel | | | | |
| Contractual | | | | |
| Operating Costs | | | | |
| Other | | | | |
| **TOTAL** | **$69,819** | **$46,546** | **$116,365** | **$116, 365** |

The Groundwater Branch of the Division of Water was reimbursed $69,819. All dollars were spent; there were no excess project funds to reallocate. The project did generate overmatch provided by the Groundwater Branch of the Division of Water. This overmatch was not posted to the Grant.

The total project budget was $116,365. The budget was expended on personnel costs reflecting a total equivalent of approximately 2.0 person years. Groundwater Branch personnel managed the project, conducted on-site inspections, sampling, and education, transported samples, interpreted sample results, prepared maps and reports, and presented the summary information to the interested parties. Water Quality Branch and Hazard Field Office personnel conducted bacteriological analyses at the Hazard Field Office laboratory. Division of Environmental Services lab personnel conducted chemical analysis at the DES lab. A time code was used to track personnel time spent on the project.

Non-personnel costs, such as travel, sampling and analysis expendable supplies, etc. were not included in the match and actually resulted in an over match of federal funds. No equipment was purchased for this project. Grant Condition #15 (QAP Plan) has been met. All tasks for this project have been completed.

## Appendix B. QA/QC for Water Monitoring

QA/QC PLAN FOR
ASSESSMENT OF NONPOINT SOURCE POLLUTION IMPACTS
ON GROUNDWATER IN THE HEADWATERS OF THE NORTH FORK
OF THE KENTUCKY RIVER BASIN

SECTION 319 NONPOINT SOURCE PROJECT WORK PLAN - FFY 1998

(formerly "Monthly Assessment of Raw Water Quality at Non-transient/Community and Unregulated Roadside Spring Public-Water-Supply Karst Springs for Nonpoint Source Pollutants")

Prepared by

Phillip W. O'dell, P.G., Groundwater Hydrologist Principal
Peter T. Goodmann, Environmental Control Manager

Kentucky Division of Water

Groundwater Branch

May 12, 1997

**On-site Wastewater Disposal - Straight Pipes**

## 2. Project Organization and Responsibility

### A. Key Personnel

| | |
|---|---|
| **Project Officer:** | Phillip W. O'dell - KY Division of Water<br>Groundwater Branch<br>14 Reilly Road<br>Frankfort, KY 40601<br>(502)-564-3410 |
| **QA Officer:** | Phillip W. O'dell - KY Division of Water<br>Groundwater Branch<br>14 Reilly Road<br>Frankfort, KY 40601<br>(502)-564-3410 |
| **Field Sampling Supervisor:** | Phillip W. O'dell - KY Division of Water<br>Groundwater Branch<br>14 Reilly Road<br>Frankfort, KY 40601<br>(502)-564-3410 |
| **Lab Supervisor:** | William E. Davis – Div. of Environmental Services<br>100 Sower Drive - Suite 104<br>Frankfort, KY 40601<br>(502)-564-6120 |
| **B.** | **Laboratory: -** KY Dept. for Env. Protection<br>Division of Environmental Services<br>100 Sower Boulevard - Suite 104<br>Frankfort, KY 40601<br>(502)-564-6120 |
| **C.** | **Assisting Organizations**: - Crystal Blackburn<br>MACED<br>PO Box 907<br>Whitesburg, KY 41858<br>(606)633-3014<br><br>Terry Anderson, Manager<br>Water Quality Branch<br>14 Reilly Road<br>Frankfort, KY 40601<br>(502)-564-3410 |

## 3. Watershed Information

### A. Water Body Name

The project area is in the headwaters of the North Fork of the Kentucky River and will be looking at groundwater resources of the area. Groundwater in the area provides 90% of the baseflow for the Kentucky River. The dissected nature of the area reduces the potential for large regional aquifer systems, so the study will be looking for clusters of nonpoint source contamination of wells in areas deemed low priority areas for water and sewer line expansion by the Letcher County Water and Sewer District to define impacted groundwater resource areas.

### B. Basin Name

The project is in the Kentucky River Basin.

### C. Stream Order

The project is a groundwater study.

### D. County(s)

The project will be conducted in Letcher County.

## 4. Monitoring Objectives

**A.** Determine groundwater resource areas which have nonpoint source pollution impacts in areas deemed low priority areas by the Letcher County Water and Sewer District.

**B.** Compile data of nonpoint source problems so that the proper agencies can use them to direct resources to implement BMP's to help minimize the impact.

**C.** Provide one-on-one nonpoint source pollution awareness with the participants of the study so that these individuals can start to understand problems associated with different activities.

**D.** Provide education regarding groundwater pollution prevention and remediating/treating polluted domestic water supplies.

## 5. Study Area Description

### A. General Description of Location

The area lies in southeastern Kentucky in the Eastern Coal Field Physiographic province.

The study area lies in Letcher County and may extend into portions of Perry and Knott Counties. Whitesburg is the largest city in the study area.

## B. General Description of the Physical Environment

### 1. Topography

The topography of the area consists of a dissected plateau characterized by narrow crooked valleys and narrow irregular steep-sided ridges. The majority of the flat, usable land is located in the valley floors.

### 2. Soils

The soils of Letcher County are generally unsuitable for conventual on-site septic systems according to the USDA (1962), as illustrated in the following table.

| **Soil Series** | **Suitability for Onsite Septic Systems** |
|---|---|
| Allegheny | Suitable |
| Berks | **Unsuitable** |
| Dekalb | **Unsuitable** |
| Gilpin | **Unsuitable** |
| Holston | Suitable on slopes less than 12 percent |
| Jefferson | Suitable on slopes less than 12 percent; **questionable on slopes of 12 to 20 percent; unsuitable on slopes of more than 20 percent** |
| Muskingum | **Unsuitable** |
| Pope | **Unsuitable** |
| Rock Land | **Unsuitable** |
| Stendal | **Unsuitable** |
| Upshur | **Unsuitable** |
| Wellston | Suitable on slopes less than 12 percent; **questionable on slopes of more than 12 percent** |

Source: Table 20 - *Interpretation of engineering properties of the soils* and *Letcher County Soil Map*, <u>USDA, Soil Series 1962, No. 1, Reconnaissance Soil Survey, Fourteen Counties in eastern Kentucky.</u>

### 3. Geology

The bedrock in the study area consists mainly of Pennsylvanian rocks of the Breathitt Formation. The Breathitt Formation consists of interbedded sandstone, siltstone and shale with interspersed coal beds. The valley floors are covered with deposits of Quaternary alluvium over bedrock.

## C. Description of the Local Hydrologic Regimes

1. Watershed Acreage

Unspecified at this time.

2. Streams and Major Basins

North Fork of the Kentucky River and it's groundwater inflow.

3. Flow Patterns

Unknown at this time.

4. Sinks

This study is not located in a karst area. Therefore, the only sinks possible are due to underground mining subsidence.

5. Relevant Groundwater Systems

The primary groundwater flow mechanism in the bedrock is fracture flow. Primary porosity is present in the sandstones but is not as important as the secondary porosity of the fractures. A hillslope stress relief fracture aquifer model applies to the valley walls in the area and these feed the shallow alluvial aquifers of the valley floors. The hydrogeology of the ridges has been extensively altered by underground coal mining operations which have operated in the area since 1910's. Groundwater flow in the Quaternary Alluvial aquifers is granular flow.

The Division of Waters Consolidated Groundwater Database shows that Letcher County is second only to Pike county in the number of water wells drilled since the creation of the database in 1986. A search of the Consolidated Groundwater database on February 25, 1997 revealed that approximately 1350 water wells have been constructed since 1985. Therefore, groundwater is a very important source of drinking water in the area.

Studies in adjacent counties show that many hand-dug wells, springs and seeps are impacted by on-site septic system contamination. However, deeper, properly constructed wells show little contamination from on-site septic systems, but do have detection's of metals possibly related to coal mining. Data generated by local health departments indicates that on-site septic system contamination may be more prevalent in Letcher County.

The dissected nature of the terrain and the presence of salt water at depth indicates continuous, extensive regional aquifers are not prevalent. Instead, many smaller aquifer basins which are controlled by the topography and geology combine to form regional aquifer systems which contribute many flows to the headwaters of the North Fork of the Kentucky River Basin. These smaller basins have not been mapped out as of yet.

## D. Description of Land-use Activities

Letcher County has areas of extremely dense housing along the stream valleys. Straight pipe discharges to the surface or streams are very common. This can be attributed to the lack of suitable land and soil conditions for conventual septic tank and lateral line installation, and to the depressed economy of the area. Trash is commonly dumped on the surface and into the creeks. Agricultural land is limited to small plots and grazing. Underground mining has be conducted extensively in the area since the 1910's with surface mining and auguring occurring more recently.

## E. Site Map

Individual site locations will be determined in the field and will depend on the willingness of individual well owners to participate. The areas which will be the focus of the study are areas of low priority for water and sewer line expansion and will be determined with the cooperation of the Letcher County Water and Sewer District and MACED.

# 6. Monitoring Program/Technical Design

## A. Monitoring Approaches and Strategies

The monitoring approach to be used is to sample as many wells as possible, making sure that the sample is as representative of the aquifer as possible. A minimum of 40 wells is planned to be evaluated. This will require the samplers to be experienced in well construction, water distribution systems, and their potential to influence the sample results. Samplers will document the water distribution system and activities around the well which could have an impact on the analysis, and sampling protocols. Screening tests will be used to limit the amount of nutrient testing in the lab and to allow more wells to be tested in the study. These screening test consist of self filling vacuum ampoules for colorimetric analysis. A vacuum in the vial draws in the correct volume of sample which reacts with the reagent and the color is compared to the color comparator in the kit. This semi-quantitative method will alert the sampling personnel to possible nonpoint source pollution and allow the personnel to make correction recommendations to the well owners at that time. Any significant detection’s by the on-site screening will be verified by the laboratory. Ten percent of the on-site screening tests will be verified by the laboratory so that the reliability of the screening can be determined. The determination of the reliability and accuracy of these inexpensive and quick methods will be useful for future nonpoint source studies as federal and state funds become less available in the future. A few of the new "test strip methods" for iron, alkalinity, nitrate and nitrite will also be compared to the lab and vacuum ampoule results. The knowledge of an approximate concentration of a nonpoint source constituent while the investigators are at the site will allow inspection of potential causes. Arrangements will be made with all the landowners to make a second sample collection visit for the microbiological samples. Do to the short holding times, the Division of Water Microbiological lab at the Hazard field office will be used and arrangements with the microbiologist in the Water Quality Branch have been made so that this second sampling event will be timed to fit their schedule.

## B. Monitoring Station Location Strategy

Monitoring sites will be to be represent regional groundwater quality with sufficient density to be able to identify areas with impacted groundwater quality. This study requires cooperation and assistance from private individuals which own or have wells at their residences. It is anticipated that there will be those who will not wish to participate and a suitable neighboring well may be used instead. Wells sampled will be ones which the owner/user has some knowledge of the wells characteristics such as approximate depth and a generalized history which will include approximate age, water quality changes over time, their perception as to causes of changes, recent repairs to pump and piping, changes in land use around the well and area, and overall information which can help determine if a situation exists in which a well or distribution system problem could mask the true quality of the groundwater resource.

Studies which do not take into consideration the distribution system and well conditions in their sampling often result in misleading or confusing conclusions which are inconsistent with the true groundwater resource conditions. This can result in large expenditures in fixes which are un-needed or misdirected. This study proposes to objectively obtain samples which are as representative of the groundwater resource as possible.

## C. Sampling Frequency and Duration

Sampling will be conducted once for the nutrient and metals testing and a second visit for bacteriological and any retesting which may be needed to verify problematic results. The results of this study will be used for prioritization of future long term studies in the areas of concern.

## D. Types of Data to be Collected

Along with the observational and spatial location data, chemical analysis will be collected. The on-site screening test will follow the manufacturers instructions and ten percent of the samples will be verified with actual laboratory analysis. Parameters proposed for on-site screening include:

| Parameter | Testing Method | Range and MDL |
| --- | --- | --- |
| Ammonia Nitrogen | Vacuum ampoule and visual comparison | 0-25 ppm and 25-250 ppm<br>MDL - 1.25 ppm |
| Nitrate Nitrogen | Vacuum ampoule and visual comparison | 0-25 ppm and 25-125 ppm<br>MDL - 1.25 ppm |
| Nitrite Nitrogen | Vacuum ampoule and visual comparison | 0-10 ppm and 10-125 ppm<br>MDL - .625 ppm |
| Detergents (anionic surfactants) | Vacuum ampoule and visual comparison | 0-3 ppm<br>MDL - .125 ppm |
| Phosphate, Ortho | Vacuum ampoule and visual comparison | 0-25 ppm and 25-250 ppm<br>MDL - 1.25 ppm |
| Sulfides (total soluble) | Vacuum ampoule and visual comparison | 0-25 ppm and 25-250 ppm<br>MDL - 1.25 ppm |
| pH | Field Meter Analysis | |
| Conductivity | Field Meter Analysis | |
| Temperature | Field Meter Analysis | |

The samples collected for laboratory analysis will comply with the following procedures and protocols for sample parameters, containerization, preservation and holding times:

## Table 1

| Parameter | Container | Preservative | Holding Time |
|---|---|---|---|
| Bulk Parameters<br>Alkalinity<br>Chloride<br>Conductance<br>Fluoride<br>pH<br>Sulfate<br>Nitrate Nitrogen<br>Nitrite-Nitrogen | 1000 ml plastic | Cool to 4$^{o}$C | <br>14 days<br>28 days<br>28 days<br>28 days<br>2 hours<br>28 days<br>48 hours<br>48 hours |
| Nutrients<br>Ammonia-Nitrogen<br>Total Kjeldahl-Nitrogen | 1000 ml plastic | $H_2SO_4$ to pH <2<br>Cool to 4$^{o}$C | 28 days |
| Orthophosphate | 1000 ml plastic | Filter on site<br>Cool to 4$^{o}$C | 48 hours |
| Metals<br>Aluminum, Magnesium<br>Antimony, Manganese<br>Arsenic, Phosphorus<br>Barium, Selenium<br>Beryllium, Silicon<br>Boron, Silver<br>Cadmium, Strontium<br>Calcium, Sulfur<br>Chromium, Thallium<br>Cobalt, Tin<br>Lead, Sodium<br>Zinc | 1000 ml plastic | Filter on site<br>$HNO_3$ to pH <2<br>Cool to 4$^{o}$C | 6 months |
| Bacteria<br>Total Coliform Bacteria<br>Fecal Coliform Bacteria<br>Fecal Streptococci Bacteria | 100ml Sterile plastic with sodium thiosulfate tablet | Cool to 4$^{o}$C, Sodium Thiosulfate tablet | <br>24 Hours<br>6 Hours<br>6 Hours |

**7. Chain-of Custody Procedures**

**A. Procedures and Forms**

A questionnaire form will be developed to accompany the standard KDOW well and KDOW spring inspection forms and standard KDOW Chain of Custody forms. These forms will be provided to KDOW, NPS Section for review and approval prior to there use. This will provide data will be entered into the Consolidated Groundwater Database.

**B. Specific Sample Preservation Needs**

Necessary preservatives (see Table 1) are added in the field; preservatives for dissolved constituents are added after field filtration. Samples are stored in coolers packed with ice for transport to the DES laboratory in Frankfort.

**C. Standardized Field Tracking Forms**

Sampling personnel will complete a Chain-of-Custody Record form for each sample and follow the standard KDEP Chain-of Custody protocol.

**D. Laboratory Sample Custodian**

The laboratory sample custodian for this project will be William E. Davis or his designee.

**8. Quality Control Procedures**

**A. Container and Equipment Decontamination Protocols.**

1. All sampling supplies that contact the sample are new, disposable equipment, or decontaminated prior to and after each use, using the following protocols.

2. Sample collection equipment, such as bailers and buckets, will consist of Teflon if available. Disposable bailers are preferable. Any reusable equipment is decontaminated with a 10% hydrochloric acid (HCL) solution, triple rinsed with deionized water, and triple rinsed with water from the sampling source prior to collecting a sample. After sampling is complete, excess sample is disposed, and the equipment is again rinsed with 10% HCL solution and triple rinsed with deionized water.

   New 0.45 micron filters are used at each sampling site for samples requiring filtration. Any tubing that contacts the sample is also new. Any reusable filter apparatus is decontaminated in the same manner as sample collection equipment. Additionally, any intermediary collection vessel is triple rinsed with filtrate prior to use.

3. Field meter probes are rinsed with deionized water prior to and after each use.

## B. Field Measurements and Equipment Calibration

Conductivity, temperature, and pH are measured in the field at each site using portable temperature compensating meters, and recorded in a field log book. Meters are calibrated according to the manufacturer's specifications, using standard pH buffer solutions. Meter probes are decontaminated according to decontamination protocols for field meters and stored according to the manufacturer's recommendations.

## C. Sample Collection, Preservation and Contamination Prevention

Water samples are fresh groundwater collected prior to any type of water treatment. Samples not requiring field filtration are collected directly in the sampling container. Samples requiring field filtration are collected in a Teflon bucket decontaminated in accordance with decontamination protocols for sample collection and filtration equipment, filtered, and transferred to the appropriate container.
Sample containers are new or laboratory-decontaminated in accordance with Division of Environmental Services accepted procedures. Sample containerization, preservation, and holding-time requirements are provided in Table 1. Necessary preservatives are added in the field; preservatives for dissolved constituents are added after field filtration. Samples are stored in coolers packed with ice for transport to the DES laboratory in Frankfort.

Sample containers are labeled with the site name and AKGWA number, sample collection date and time, analysis requested, preservation method, and collector's initials. Sampling personnel complete a Chain-of-Custody Record for each sample. The DES laboratory is responsible for following approved laboratory QA/QC procedures, conducting analyses within the designated holding-times, following EPA-approved analytical techniques, and reporting analytical results to the Groundwater Branch within sixty days of sample receipt.

## D. Duplicates and Blanks

At least one duplicate sample will be submitted with each batch of samples, regardless of the number of samples in the batch. Blanks of deionized water will be submitted at least once during the study. Blanks will be collected, filtered, and preserved in the same manner as a sample.

## E. Acceptable Levels of Variance

## F. Laboratory's Standard Operating Procedure

The DES laboratory will follow their SOP for analytical analysis.

## G. Procedures for Unacceptable Results

A second confirmation sampling event has been scheduled for sample locations that may require verification/resampling. The QA Officer and hydrogeologist will examine the data to determine which results, if any are unacceptable or unreasonable. These sample locations maybe resampled to correct the problem.

## 9. Other

### A. Wells

Small diameter wells, such as six-inch diameter private wells, are pumped for at least five minutes, or a sufficient time to purge three to five well volumes from the well, prior to sampling to ensure that fresh formation water is sampled. Large diameter wells, such as municipal supply wells, will be evaluated on a case-by-case basis to determine whether they can be efficiently purged, or whether they have already been pumped sufficiently to ensure that fresh formation water is sampled without additional purging.

Samples are collected as close to the well as possible. Multiple well systems are sampled from a point in which the designated sampling well is isolated from other wells. Wells without pumps are avoided to the extent possible due to the time necessary to manually purge the well. However, in the event that a well that uses a bailer as the water delivery is encountered, it must be purged manually, preferably with the bailing equipment already installed on the well. Hand-dug wells may have too large of volume or too slow of recharge to purge the well of 3 to 5 well volumes before sampling. In this case, the system should be run at high flow for at least 5 minutes to purge the lines of any stagnate water before sampling.

### B. Springs

Spring samples are collected as close as possible to the spring resurgence with samples collected from the spring house or basin being preferable. If access to the spring, spring house or spring box is not possible, the system should be purged for at least 5 minutes to clear the lines of stagnate water before sampling.

## 9. Unique Aspects of the Project

Letcher County is currently planning for sewer and water extensions into rural areas of the county. The data gained from this study will be valuable for their planning and prioritizing future projects with the limited funds available. Areas with the highest nonpoint source groundwater resource impacts can be given earlier attention and focus.

The project plans to work closely with MACED and local government which will provide hands on training on groundwater, wells, and nonpoint groundwater pollution. A presentation of the results will be prepared for the local Letcher County Water and Sewer District and the Letcher County Fiscal Court. The one-on-one nonpoint source educational component to be included into the sampling, interview, and inspection process will present the concept of nonpoint source pollution and the potential effects to a number of individuals in an informal, non-regulatory manner. Previous studies conducted by the Groundwater Branch have resulted in post-study public meetings which had extremely poor turnouts. The one-on-one training allows concepts to be presented to everyone which allows us to sample their well, using examples from their immediate area in the discussion.

## 10. References


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